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Procedia Computer Science 86 (2016) 289 – 292

Procedia Computer Science

2016 International Electrical Engineering Congress, iEECON2016, 2-4 March 2016, Chiang Mai, Thailand

The design of electrode for partial discharge location simulation in oil insulated power transformer and the application of AE method

Pinit Jitjing[a] *, Thanapong Suwanasri[b] and Cattareeya Suwanasri[b]

[a] *Electrical Engineering. Dept. Rajamangala University of Technology Thanyaburi Pathum Thani, Thailand*
[b]*The Sirindhorn International Thai-German Graduate School of Engineering King Mongkut's University of Technology North Bangkok, Bangkok, Thailand*

Abstract

This paper presents the design of electrode for PD-location simulation in oil insulated power transformer and the application of Acoustic Emission (AE) method. The purpose of this design is to make a simple PD signal simulation and to save the time of experiment. The design must take into account the electric field stress at the electrodes (anode) that will cause PD. The electrodes were designed as 2 types. The first is a conventional electrode expected to make a high nonuniform field. The second electrode was designed as insulation layer and transformer coil to generate higher nonuniform field and expected to cause PD easily. Electrodes were simulated to determine the maximum of electric field by installing in the transformer model. Then, the electrodes are installed in the transformer model to make the real test by supplying high voltage to the electrodes to generate PD signal. From the measurement results of PD-location in the power transformer model according to AE and TDOA method found that, the first electrode has uncertain PD-location measurement results. Moreover, it take so long time of any experiment to obtain PD-signal and sometimes become critical breakdown as a result to damage measurement device. While the PD-location detection results from the second electrode found that it can be easily simulated PD signal. The PD-location result has a better precision or has statistical data to detect PD-location explicitly. Therefore, this special designed electrode could be applied for PD detection study in power transformer or other electrical equipment as well.

Peer-review under responsibility of the Organizing Committee of iEECON2016

Keywords: Power Transformer; Electrode; Partial Discharge Location; AE Method

* Corresponding author. Tel.: +662 549 3569; fax: +662 549 3422.
E-mail address: pinit.j@ en.rmutt.ac.th

Peer-review under responsibility of the Organizing Committee of iEECON2016
doi:10.1016/j.procs.2016.05.074

1. Introduction

Several years ago, so many researches had tried to present many methods about the partial discharge detection and location in power transformer. The benefit of PD localization in power transformer is the possibility to estimate the severity of the occurred problem inside power transformer. The known information of PD detection and its location can be further used for determining the proper action whether to do maintenance or immediate repair. Some research report has presented the simulation method, location detection and experiment study[1-3]. Some research report has presented the design of electrode in their experiment[4, 5]or some report has tried to simulate the real transformer model[6, 7]. For my last 3 years' experience about the study on location of acoustic emission partial discharge detection in transformers, I have found that, one of the difficulty about the experiment is the electrode design. If one want to study about the PD-location, one need to energize the PD signal at the desire position and desire time. This paper will present the alternative how to design the electrode for PD-location simulation in oil insulated power transformer. The calculation and simulation of electric field in transformer model have been managed first and then the PD-location experiment with the application of AE method has been used to prove the accuracy.

2. Transformer model and Electrode Design

As in Fig. 1, the transformer model for PD-location simulation has been designed. The 3 adjustable electrodes have been put into the tank together with transformer oil fill. The top electrode (Anode) has designed into 2 models as in Fig. 2 (a) and (b). The top electrode No.1 is as copper with sharp ended rod shape. It is conventional rod electrode and expect that it would give highly non-uniform field. The top electrode No.2 is also the same as the top electrode No.1 addition with ring laminated at the ended rod. The reason to design the top electrode No.2 is expect that, it would give very high non-uniform field at this point and easy to simulate the PD-signal. The bottom plate electrode is as cathode with rogowski profile.

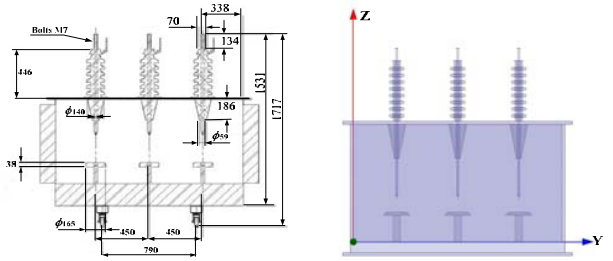

Fig. 1. Transformer Model with 3 adjustable Electrodes inside.

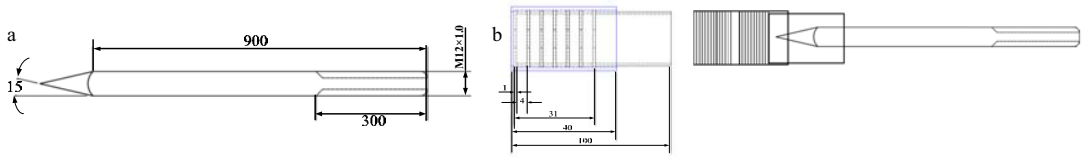

Fig. 2. (a) Top electrode No.1 (b) Top electrode No.2

2.1. Field Utilization Factor

For top electrode No.1, it could be calculated the field utilization factor (η^*) according to equation (1) – (3)[8]. If the radius (r) is constant designed, the field utilization factor of any distance (S) could be calculated and the maximum electric field at the ended rod could be known for specific breakdown voltage (U_b).

$$\eta^* = \frac{1}{f} = \frac{E_{mean}}{E_{max}} \tag{1}$$

$$E_{mean} = U_b / S \tag{2}$$

$$f = 0.85 \times \left(1 + \left(S/r\right)\right) \quad (3)$$

When: S distance of electrode gap (cm) U_b breakdown voltage (kV) (kV/cm)
r radius of ended rod (cm) E_{mean} average electric field E_{max} maximum electric field (kV/cm)

2.2. Electric Field of Electrode Simulation Result

For top electrode No.2, it could not be calculated the field utilization factor, because the electrode is complicated designed. As in Fig. 3 shown the electric field simulation of 3 electrodes in transformer model (a) and maximum of electric field at the ended rod of 3 electrodes (b).

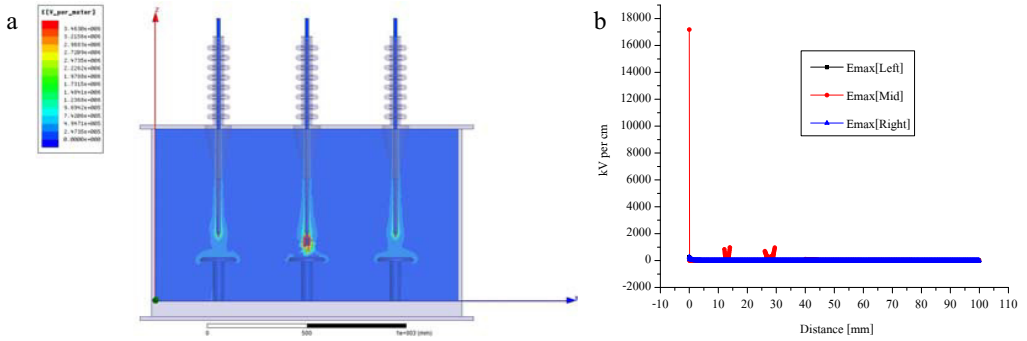

Fig. 3. (a) Electric field simulation of 3 Electrodes (b) E_{max} of 3 Electrodes

It was found that, the maximum electric field of electrode No.2 is extremely higher than electrode No.1. Therefore, it is confident that. The PD-signal could be easily simulated and the duration of experimental time would be saved.

3. PD Location Experimental Procedures and Result

The PD-origin was simulated in oil-filled transformer model and all equipment were setup as in Fig. 4 (a). The high voltage source was connected to the top electrode until PD occurs. The measurement results of PD-location in the power transformer model according to AE and TDOA method[9].

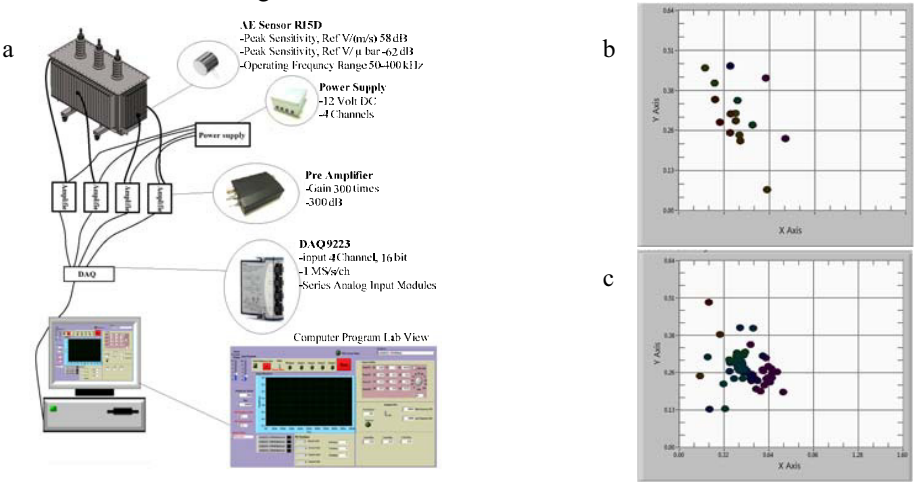

Fig. 4. (a) PD-location measurement (b) PD-location detection No.1 (c) PD-location detection No.2

3.1. PD-Location Experiment Setup

As shown in Fig. 1, the electrode No.1 and No.2 have been setup into the transformer model and managed the desire position. Any electrode has been tested separately by using "auto save mode" of PD-detection program. The time of test for any position was taken about 30 minutes.

3.2. PD-Location Detection Result

As in Fig. 4 (b) shown the PD-location result of electrode No.1. It was found that, the PD-detection could be appeared at anywhere in transformer model and so difficult to simulate the PD-signal. As in Fig. 4 (c) shown the PD-location result of electrode No.2. The PD-detection could be appeared at anywhere in transformer model too but, the most PD-location was appeared at the desired position.

4. Conclusion

The design of electrode for PD location simulation on this paper is just one of the alternative recommended model for using as the study of PD location. It could be applied for using with any transformer or electrical equipment model. With any PD detection method, it could be easy to simulate the PD signal and all instrument would be saved, because it has no critical or dangerous breakdown on any experiment. Moreover, one could control their time and material of any experiment, because in only a short time, they would have enough data from testing in order to analyze and made the conclusion.

Acknowledgements

The authors would like to thank for supporting from RMUTT High Voltage Testing Laboratory for conducting the experiment in their laboratory, many thanks to support from Prof. Dr. Wanchai Subsingha, Associate Prof. Sirichai Dangam for researching equipment and also many thanks to Mr. Paran Sritong, master student from RMUTT for PD detecting program development.

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